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CANADIAN PATENT

LINER EXPANDER

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LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed
10 through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy
20 wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the second-stage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring
30 characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.



Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a pre-selected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which
10 expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longi-
20 tudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

30 Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a first-stage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the second-stage die is drawn through the liner to expand it in place in the casing. The first-stage die provides a gross deformation of the liner so that it is expanded outwardly against the wall of the casing. The second-stage die then passes through the liner and performs the final expansion to smooth the inner surface of the liner and to provide more even contact between the liner and the wall of the casing and effect a fluid-tight seal.

In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the second-stage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 23 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. right-hand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and three-quarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

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Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into
10 which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to
20 slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

30 The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 13.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

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the artisan from the description, and, as such, these fall within the spirit
and scope of my invention.

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I CLAIM:

1 1. A device for expanding a metallic liner inside a conduit which
2 device comprises a shaft element, an expanding die member attached to said
3 shaft element, said die member comprising a movable liner-forming member
4 positioned on said shaft and being radially movable in respect thereof to
5 contact said liner, an expander member slidably positioned on said shaft
6 between said shaft and said die member to move said liner-forming member
7 from said shaft, and a constant force spring member positioned on said shaft
8 to contact said expander member and to maintain said expander member against
9 said liner-forming member, whereby said liner-forming member is urged against
10 said liner by a substantially constant force.

1 2. In a device for installing an expanded metallic liner in a
2 conduit wherein an expanding die is moved through a liner positioned in said
3 conduit to expand said liner: a cylindrical shaft element, an expanding die
4 member attached to said shaft, said die member comprising a plurality of arm
5 members disposed around said shaft and being pivotable outwardly therefrom to
6 contact said liner, a cone member slidably positioned on said shaft between
7 said shaft and said arm members to urge said arm members outwardly from said
8 shaft, and a constant force spring member positioned on said shaft to contact
9 said cone member and to maintain said cone member in contact with said arm
10 members, whereby said arm members are urged outwardly by a substantially
11 constant force.

1 3. The device of Claim 2 wherein said constant force spring member
2 comprises a plurality of columns disposed around said shaft, a first bearing
3 plate member and a second bearing plate member, each of said bearing plate
4 members contacting opposite ends of said columns, at least one of said bearing
5 plate members being movably positioned on said shaft and being in contact
6 with said cone member, stop means connected to said shaft to limit the axial
7 travel of said movable bearing plate member along said shaft, and compression
8 means for maintaining a lateral deflection in said column.

1 4. The device of Claim 3 wherein said compression means comprises
2 a differential screw connecting said spring member and said shaft.

1 5. The device of Claim 3 wherein said stop means comprises a
2 sleeve-like element connected to said movable bearing plate member and
3 slidably positioned on said shaft and a member connected to said shaft to
4 limit the travel of said sleeve-like element.

1 6. The device of Claim 3 wherein said columns have a rectangular
2 cross-section, the width being greater than the thickness, and having the
3 wider face normal to the diameter of said shaft.

1 7. A device for installing an expanded metallic liner in a conduit
2 which comprises a cylindrical shaft element; an expanding die member mounted
3 on said shaft, said die member comprising a plurality of arm members disposed
4 circumferentially around the outside of said shaft and being pivotable out-
5 wardly therefrom to contact the liner; a conical expanding member slidably
6 positioned on said shaft between said shaft and said arm members to urge said
7 arm members outwardly from said shaft; a plurality of slender columns, each
8 having a long rectangular cross-section and disposed circumferentially about
9 said shaft; an upper bearing plate member and a lower bearing plate member,
10 each slidably positioned on said shaft and contacting opposite ends of said
11 columns; limiting sleeves attached to each of said bearing plate members
12 and slidably positioned on said shaft; a shoulder member on said shaft; a
13 differential screw element connecting said shoulder and said shaft to apply
14 a buckling load to said columns; said shoulder being engageable with the
15 limiting sleeve connected to said lower bearing plate member, whereby the
16 axial travel of said bearing plate members is limited; said column members
17 transmitting their buckling load to said arm members to urge said arm members
18 outwardly with a substantially constant force.

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LINER EXPANDER

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inlet

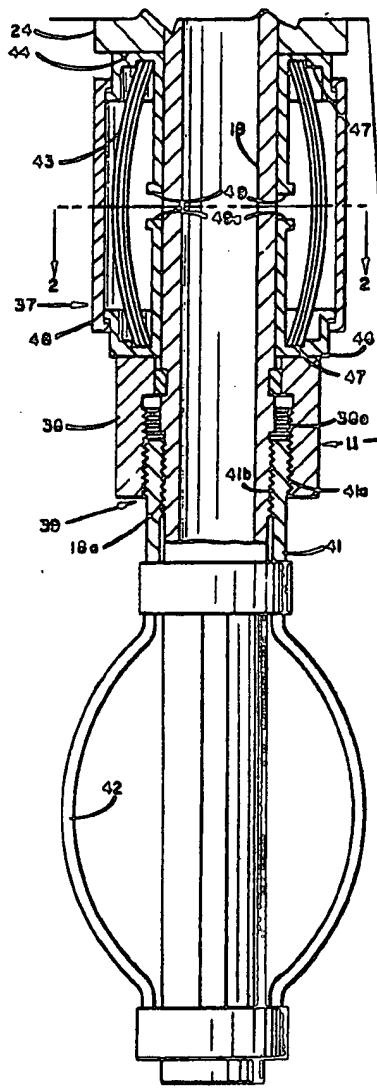


FIG. 1A

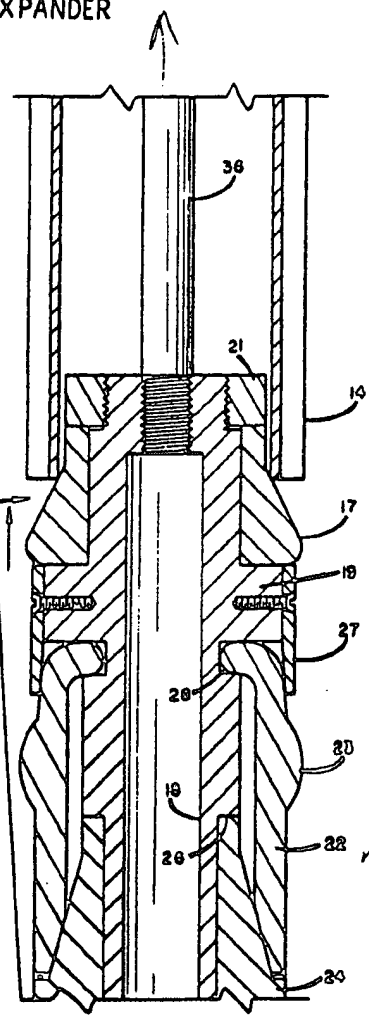


FIG. 1B

movable
wires

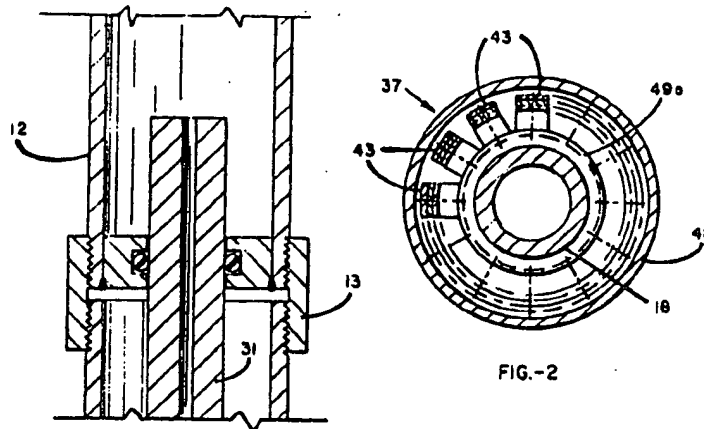


FIG. -2

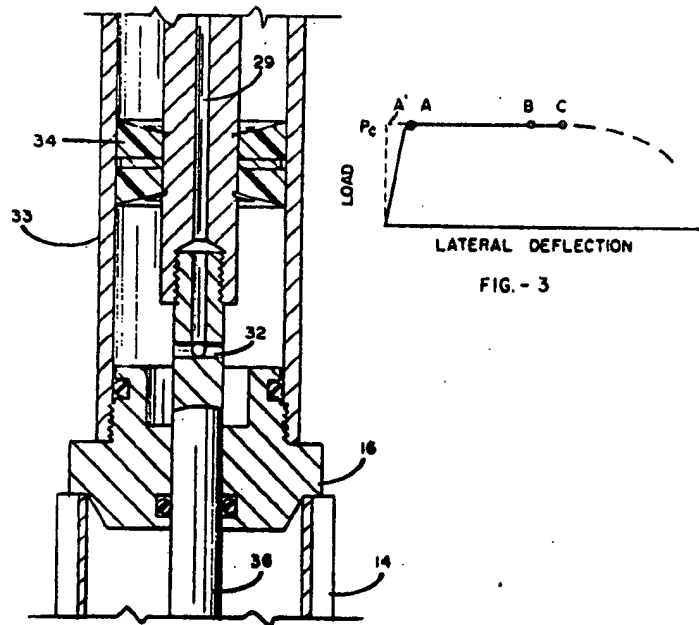


FIG. -1C

FIG. -3

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I CLAIM:

1. A device for expanding a metallic liner, which a contact which
 2 device comprises a shaft element, an expanding die member attached to said
 3 shaft element, said die member comprising a movable linear-forming member
 4 positioned on said shaft and being axially movable in response thereof to
 5 contact said liner, an expander member axially positioned on said shaft
 6 between said shaft and said die member to urge said linear-forming member
 7 from said shaft, and a contact force spring member positioned on said shaft
 8 to contact said expander member and to maintain said expander member against
 9 said linear-forming member, thereby said linear-forming member is urged against
 10 said liner by a substantially constant force.

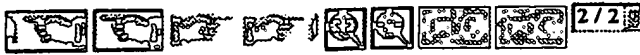
2. In a device for installing an expanded metallic liner in a
 3 contact chamber in a cylinder die is moved through a liner positioned in said
 4 contact to expand said liner, a cylindrical shaft element, an expanding die
 5 member attached to said shaft, said die member comprising a plurality of arm
 6 members disposed around said shaft and being pivotable radially therefrom to
 7 contact said liner, a cone member axially positioned on said shaft between
 8 said shaft and said arm members to urge said arm members radially from said
 9 shaft, and a contact force spring member positioned on said shaft to contact
 10 said cone member and to maintain said cone member in contact with said arm
 11 members, thereby said arm members are urged radially by a substantially
 12 constant force.

3. The device of Claim 2 wherein said contact force spring member
 4 comprises a plurality of springs disposed around said shaft, a sleeve bearing
 5 plate member and a second bearing plate member, each of said bearing plate
 6 members contacting opposite side of said sleeve, at least one of said bearing
 7 plate members being axially positioned on said shaft and being in contact
 8 with said cone member, stop means connected to said shaft to limit the axial
 9 travel of said sleeve bearing plate member along said shaft, and compression
 10 means for maintaining a lateral compression in said sleeve.

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B





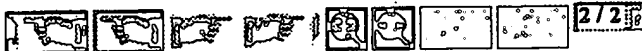
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- 1 4. The device of claim 3 wherein said compression zone comprises
- 2 a differential screw assembly with spring member and said shaft.
- 3 5. The device of claim 3 wherein said stop means comprises a
- 4 sleeve-like element connected to said movable bearing plate member and
- 5 radially positioned on said shaft and a member connected to said shaft to
- 6 limit the travel of said sleeve-like element.
- 7 6. The device of claim 3 wherein said column has a rectangular
- 8 cross-section, the width being greater than the thickness, and having the
- 9 outer face parallel to the diameter of said shaft.
- 10 7. A device for installing an expanded metallic liner in a conduit
- 11 which comprises a cylindrical shaft assembly, an expanding die member mounted
- 12 on said shaft, said die member comprising a plurality of vanes disposed
- 13 circumferentially around the outside of said shaft and being pivotally con-
- 14 nected to a central rotating member rotatably
- 15 positioned on said shaft between said shaft and said die member to urge said
- 16 vanes radially from said shaft; a plurality of sleeve columns, each
- 17 having a long rectangular cross-section and disposed circumferentially about
- 18 said shaft; an upper bearing plate member and a lower bearing plate member,
- 19 each radially positioned on said shaft and extending opposite ends of said
- 20 column; limiting elements attached to each of said bearing plate members
- 21 and slidably positioned on said shaft; a shoulder member on said shaft; a
- 22 differential screw assembly connecting said shoulder and said shaft to apply
- 23 a bearing load to said column; said shoulder being connected with the
- 24 limiting element connected to said lower bearing plate member, thereby the
- 25 axial travel of said bearing plate member is limited; said column members
- 26 transmitting their bearing load to said vanes member to urge said vanes
- 27 outwardly with a substantially constant force.

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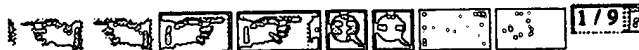
LINER REMOVAL

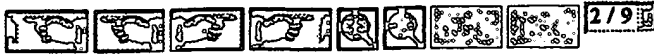
This invention relates to a mechanical force spring device, and more particularly, to a device for separating a metallic liner therein an expanding die is urged against the liner by a mechanical force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a compressed steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is forced through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is urged outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional liner deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to secure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die explains the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the expanding forces can cause the tool to become stuck in the casing or otherwise cause damage to the casing and the tool. In other designs, such as those a continuous spring arrangement is employed in connection with the second-stage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool to work which enters an circumference will become stuck in the wall or when being to the wall. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

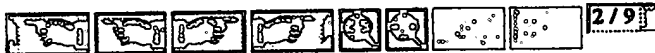
An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a pre-selected random force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a cavity, which
 20 expanding tool can apply as pressure than a predetermined force to the liner being installed in the cavity. Still another object of the invention is an improved and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

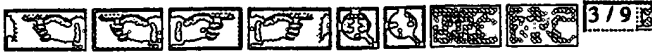
In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated coil almost adjacent said body member, bearing plate members enclosing the two ends of said coil at least one of said bearing plate members being longitudinal
 25 essentially movable in respect of the other and spring means on said body member to limit the deflection of said coil almost to prevent permanent deformation of said coil almost upon the application of a compressive load thereon. In an embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a cavity, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the cavity by a substantially constant force.

The invention will be better understood by reference to the following description and the accompanying drawings wherein:

30 FIGURES 1A, 1B and 1C, taken together, constitute a partial cross-sectional view of a preferred embodiment of a liner expanding tool according to the present invention and

- 2 -





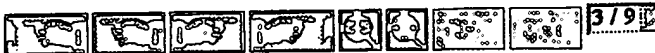
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Figure 2 is a sectional view of the apparatus of Figure 1A taken at lines 2-2; and

Figure 3 is a typical plot of applied load versus deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a linear expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 2B shows the upper portion of the tool. The expanding tool 11 is attached to a cement wall 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated partially corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 15 and, at the lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a first-stage expanding die in the manner hereinafter described. The expanding die 17 is firmly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with externally elongated portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The elongated portions of the arms 22 upon being moved outwardly contact the liner to portion the final step of expanding the corrugated liner into a substantially cylindrical shape. The arms 22 are pivotally attached to the shaft 18 so as to be movable radially from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, tapers outwardly along the shaft to engage with the arms and move them outwardly. Advancement of the inner surfaces of the arms 22 and the outside surface of expanding member 24 from cutting position, typically conical in shape. The expansion of the arms 22 is controlled by the position of the member 24 which moves axially

- 3 -





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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 12 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular grooves 28 provided on the shaft.

The expanding seal, comprising the first-stage die and the second-stage die is drawn through the liner to expand it in place in the casing. The first-stage die provides a gross deformation of the liner so that it is expanded outwardly against the wall of the casing. The second-stage die then passes through the liner and performs the final expansion to match the inner surface of the liner and to provide more even contact between the liner and the wall of the casing and effect a fluid-tight seal.

In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrected tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through joints 32 and into cylinder 33 connected to the upper end of the shoulder 34. Upon the application of fluid pressure to the cylinder, the piston 34 moves to polished rod 31 moving upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the second-stage die 21 are drawn upwardly into the corrected liner 10 and "line out" the compression in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to trip the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing wall is substantially constant so that either stretching of the seal in the casing or rupture of the casing is precluded. Of course, the stress provided by the spring member is precluded so that the frictional





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forces between the tool and the liner and the pressure exerted against the lining are maintained at predetermined safe levels. The constant force spring member ensures that the contact pressure between the liner forming portion 33 of the cone 32 is great enough to provide the desired deformation of the lining, while preventing damage to the lining or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the depending element 35 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are male threads 40a, the lower shoulder member 38 provided with female threads 40b and shoulder member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to mesh with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to shoulder 41. The shoulder 38 is secured to the shaft 18 by splines 42 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the shoulder is a friction member, such as the spring 43, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the casing to secure the shoulder against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 40b is the same as that of the shaft threads 40a, e.g. right-hand threads, and the pitch, or lead, of threads 40b is slightly greater than that of threads 40a, with the pitch ratio being close to unity. In this manner, clockwise revolution of the shaft relative to the shoulder member 38 to advance upward slightly and a corresponding lead so secured upwardly on spring element 37 to cause twisting. For example, an satisfactory differential screw was made by using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and three-quarters threads/inch square threads on a shoulder approximately 2.5-inch outside diameter.

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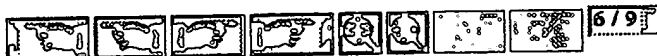
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Constant force spring element 31 comprises element 43, conventionally comprising a plurality of elongated coils arranged around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the coils and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expansion member 24. Lower bearing plate member 45 contacts the lower ends of the coils and is moved axially along the shaft by longitudinal movement of lower shoulder 33 as a result of revolving differential cover element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the coils are inserted. These grooves may be shaped to conform with the shape of the coils ends if desired. A cover 48 may be employed to enclose foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the coils is required. Although the coils element functions in a balled construction, application of excessive compressive load stresses would cause total failure or rupture of the coils. Therefore, a pair of stops 49 and 50 are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect, operate upon the lower limiting element positioned on the shaft to slide longitudinally thereon. The ends of the stops may curve inward, or may face each other on the ends in the spring member started. Lower sleeve 51 is provided from coating 46 by lower shoulder 33 connected to the shaft 18. However, the spacing between the coils is such as to limit the longitudinal travel of the bearing plates when they move together to prevent permanent deformation of the coils element 43. Various alternative means for preventing damage to the coils element may also be employed. For example, pins or rings mounted on the shaft may curve or slope, or the cover 48 provided with suitable construction may be employed for this purpose to limit longitudinal and/or lateral deflection of coils.

The coils of the coils element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the coils fitted in the races 47. The coils may be

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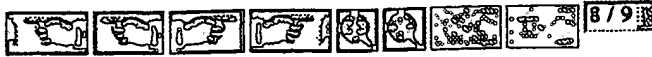
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fitted closely together on shaft, or may be spaced around the shaft, with spacers used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the endomorph ratio of the column may be varied widely, and the column ends may be round, flat, flared or beveled. The preferred construction is a thin, slender column with rounded ends, free to move within the space defined by the members of the column ends. Materials which may be satisfactorily employed for the columns are certain cast low alloy steels, chrome and nickel-chrome stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the lateral columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the column is normal to the axis of the shaft. Thus, with sufficient compression loading, the column buckles, and bends about the axis having the least moment of inertia, e.g., radially away from the shaft.

For example, a group of columns 0.187-inch thick by 0.393-inch wide by 19.625-inches long, with the ends rounded, were fabricated from A.I.S.I. 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After loading, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_0 is the critical loading load and point Q represents the load and deflection at which the stress in the column fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve (A) in Figure 3. Actually, this curve is described by curve (B) due to friction in the system. Points A and B represent typical loading limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a loading limit just below the yield point may be used, while with a great number of flexures, the loading stress may be held to less than the endurance limit of the material of construction. In the above-cited tests, the lateral deflection was limited to

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approximately one inch, at which the longitudinal deflection was approximately 0.05 inches. From zero deflection to the maximum deflection, the 150-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 80 coils, each having a critical buckling load of 1850 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at approximately 13,600 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 13,600

10 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the column at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat coils making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the make-up tool is lowered into the well as mentioned above, with the arm 22 in the retracted position. When the tool is at the desired level, the arm 22 is extended. The friction member 19 engages with the wall of the casing and prevents the tool 41 from revolving. When several revolutions of the tool, lower shoulder 25 is moved axially by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted axially against the lower end of member 24, and its tapered portion is engaged with the tapered portion on the lower end of the arm 22 to urge the arm axially with a substantially constant force proportional to the critical buckling load of the spring element. Consequently, the expanding tool is forced through the liner to expand it in the casing in the manner described heretofore.

20 and foregoing description of a preferred embodiment of my invention has been given for the purpose of amplification. It will be understood that various modifications in the details of construction will be apparent to

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the articles from the description, and, as such, these fall within the spirit
and scope of my invention.

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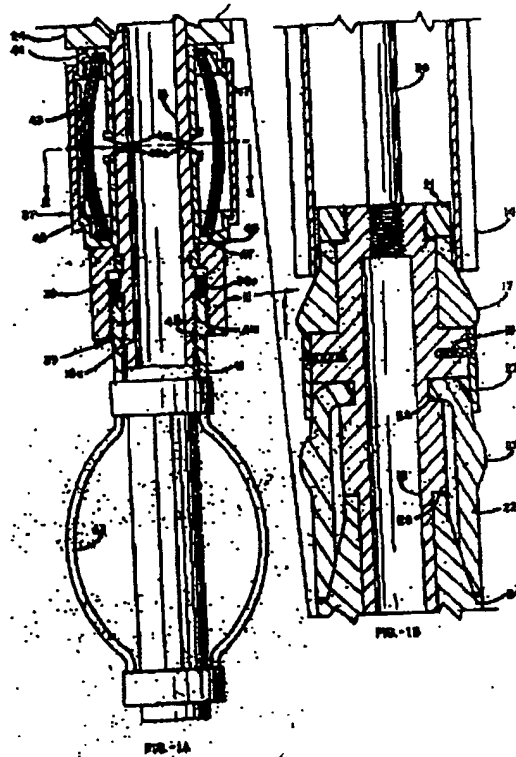
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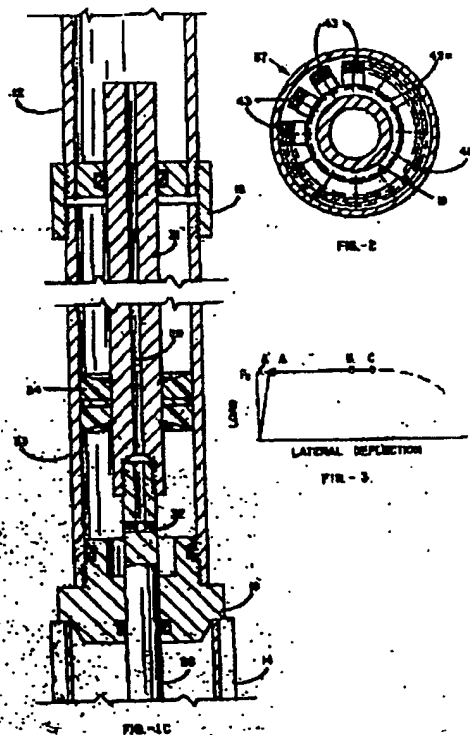


FIG. 1A



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